Reducing Oxides of Nitrogen Emissions

From Industrial Boilers To Meet Virginia's SIP Call Budget

By

State Advisory Board Committee
On
Boiler NOx Controls

November 8, 2000

1. Introduction

The Environmental Protection Agency (EPA) on March 2, 2000 (65 FR 11,222) finalized the Virginia Oxides of Nitrogen (NOx) reduction budget. This requirement for NOx reductions came about after a prolonged and sometimes contentious public comment and review period.

Oxides of nitrogen (NOx) form during combustion processes when oxygen and nitrogen react. These NOx molecules enter the atmosphere primarily from utility/non-utility boiler stacks and mobile sources. Volatile organic compounds (VOC) from solvents and fuels evaporate into the atmosphere. Coexisting NOx and VOC molecules, when energized with strong solar radiation, form ozone (O_3). Ozone makes up the major component of smog. Reductions in NOx reduce ambient ozone concentration levels.

Computer modeling with ozone precursor emissions provided the basis for projecting the reduction in tons of NOx per ozone season needed to bring about ambient ozone concentration reductions to meet ozone standards. The reduction of NOx emissions specified in EPA's NOx SIP call serves to reduce ambient ozone concentrations during the summer ozone season between the beginning of May and the end of September. Reducing ozone concentration levels will reduce adverse impacts on human health, forests, crops and visibility. This report directs attention to options available for NOx emissions reductions from industrial boilers in Virginia.

EPA's classification uses "Non-EGUs", non-**e**lectrical **g**enerating **u**nits, as a label for industrial boilers that exist mainly for generating steam and not electricity for sale.

The primary component of the National Ambient Air Quality Standard (NAAQS) for ozone specifies the maximum ambient ozone exposure levels "requisite to protect the public health". The State Implementation Plan (SIP) modification, designed to meet the NOx SIP Call, provides the Virginia Department of Environmental Quality (DEQ) a means for detailing Virginia's approach to attaining the NOx emissions reductions required by the EPA SIP call.

The EPA call for NOx emissions reductions aims at reducing measured ozone levels in Virginia and a number of other states to NAAQS levels. This report discusses approaches for DEQ use in bringing about NOx emissions reductions from Non-EGUs in Virginia. Reductions of NOx emissions by Non-EGUs must be sufficient to allow Virginia to comply with the Virginia part of the general EPA NOx SIP call.

Proposed SIP modifications to reduce boiler NOx emissions, must convince EPA that implementing the plan will reduce NOx emissions from Non-EGU units by 6,892 tons per ozone season. This SIP compliance strategy must detail and quantify the methodology that will be used to reduce Virginia NOx emissions from 42,108 to 35,216 tons per ozone season by May 31, 2004. According to EPA, this reduction when combined with NOx reductions by 21 other states and the District of Columbia, bring about a regional improvement in O_3 that will lead to state and regional compliance with the NAAQS for ozone.

2. EPA's NOx "SIP Call"

EPA's SIP Call rule was finalized on September 24, 1998. P. Brown, Comment: Lofty Goals, Questioned Motives, and Proffered Justifications: Regional Transport of Ground-Level Ozone and the EPA's NOx SIP Call, 60 U. Pitt. L. Rev. 923 (Spring 1999). Its primary mechanism for reducing regional transport of ozone (RTO) is the setting of nitrogen oxide emissions budgets for the 22 states east of the Mississippi and the District of Columbia.

Table 1 NOx Emissions Budget for Virginia

65 Fed. Reg. 11,222 (March 2, 2000)

Electric Generating Units (EGUs)	
Baseline	40,884 tons/season
Budget (58% reduction)	17,187
Reduction	23,697
Non-EGUs	
Baseline	42,108
Budget (16% reduction)	35,216
Reduction	6,892
Stationary Area Sources	
Baseline	27,738
Budget (0 reduction)	27,738
Nonroad mobile (tractors, airplanes, loggers, bulldozers, tree cutters)	
Baseline	27,859
Budget (0 reduction)	27,859
Highway mobile	
Baseline	72,195
Budget (0 reduction)	72,195
Totals	
Baseline	210,784
Budget (15% reduction)	180,195
Reduction	30,589
Compliance supplement pool	5,504

A NOx budget is a cap on the overall tonnage of NOx that a covered state can emit during a single ozone season. See Finding of Significant Contributions and Rulemaking for Certain States and the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 63 FR 57,356, 57,405 (September 24, 1998) (to be codified at 40 C.F.R. Parts 51, 72, 75, and 96).

Overall the NOx SIP Call requires approximately a 1.1 million ton NOx reduction each ozone season for all 23 covered jurisdictions (22 states and the District of Columbia). States, in turn, distribute NOx emission allowances, the sum of which may not exceed each state's budget, to stationary sources within the state. States retain the authority to allocate allowable emissions as part of the State Implementation Plan (SIP) process.

As noted already, EPA published revised budgets for each of the 23 jurisdictions in the Federal Register on March 2, 2000. 65 FR. 11,222 (March 2, 2000). Table 1 lists the "baseline" and "budget" numbers for Virginia. "Baseline" refers to EPA's calculation of the total emissions of NOx that would occur in the year 2007 without the SIP Call. "Budget" is the reduced emissions allowed by the rule.

In short, Virginia must find a way to reduce its NOx emissions by 15%, or 30,589 tons in each ozone season (the months May through September, a five-month period). As the above table makes clear, EPA proposes to achieve the budgets by reducing emissions from electric generating units (EGUs) and large industrial boilers, ones greater than 250 mmBTU-per-hour heat input. This report deals NOx reduction approaches to apply to the industrial boiler part of the program.

3. Non-EGU NOx Emissions Reductions

Significant approaches for reducing Non-EGU NOx emissions are:

1. Institute a program of trading NOx allowances
2. Install proven pollution controls for NOx
3. Improve operation and maintenance of NOx-emitting stationary sources along with the implementation of energy audits and Energy Management Practices for NOx Reduction Credits
4. Reduce NOx emissions from vehicles (mobile sources)

The State Advisory Board explored the issue of trading NOx allowances in 1999. A DEQ ad hoc advisory group is exploring a trading program. Therefore this report does not include a discussion of emissions trading as a tool for NOx reduction. Expensive end-of-pipe NOx controls have been proven (vendors will guarantee performance) which prompted the boiler NOx controls advisory group not to discuss that option in this report. In no way does this imply that end-of-pipe NOx control will not be needed but does imply that the end-of-pipe controls should be viewed as the expensive option for use after all of the other less expensive approaches have been reviewed.

The boiler NOx Controls Committee focused this year on the last three of the four approaches listed above. Option 3 deserves attention because:

- Improved operation and maintenance reduces fuel use and thus reduces NOx emissions
- Improved operation and maintenance reduces the cost of purchased fossil fuel energy, which produces a "win-win" proposition. Recent escalating energy costs make this an even more viable option now than in past years.

- Operation and maintenance is a neglected area, often overlooked by operators and those with fiscal responsibility

Substantial savings in fuel, dollars, and emissions can be acquired by improving boiler operations, operator training, and facilities maintenance.

Examples found in the literature:

- A reduction of 40°F in the stack temperature increases efficiency by about 1%. ⇒ heat exchanger maintenance
- Every 11°F added to boiler feed water increases efficiency by 1%
- A scale build-up of 1/8 inch can increase fuel consumption as much as 4% ⇒ boiler tube cleaning and repairs
- A soot build-up of 1/8 inch can increase fuel consumption by as much as 8%.
- The cost for a 1/2-inch steam leak at 100 PSIG could be as much as $75,000 per year.⇒ monitored by condensate return records
- The most effective immediate solution to reducing greenhouse gas emissions (carbon dioxide, for example) is efficient energy use.[1]
- Energy management pays, and it pays considerably. Companies with comprehensive energy plans report 20% savings.[2]
- An extensive survey of more than 260,000 steam traps in 40 large steam-using industrial plants showed that, on average, only 58% were working correctly.[3]

Industrial Boilers convert essentially pure water into steam. After use, most of the partially condensed steam returns as a steam condensate mixture. When operating properly, steam traps block the return of the steam component while allowing the condensate to return to the boiler feed pump.

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[1] *Turner, Wayne, Ph.D., P.E., Energy* Engineering, *Vol. 96, No. 6, 1999.*

[2] *Payne, William F.,* Strategic Planning for Energy and the Environment, *Vol. 19, No. 2, 1999.*

[3] *Payne, William F.,* Strategic Planning for Energy and the Environment, *Vol. 19, No. 2, 1999.*

Malfunctioning steam traps make it necessary to vent the steam fraction of the mixture to the atmosphere. This steam waste requires not only expensive chemical treatment to replace pure water lost but also requires an increased fuel feed rate to replace the wasted energy. This increased fuel demand, estimated to be in the 20% range in Virginia, obviously wastes money but not so obviously increases NOx and other stack emissions by approximately 20%.

Consultation with experienced personnel with 100-250-mmBtu/hour-sized boilers expertise revealed the following:

1. Boiler operators need training and special instrumentation to adequately assess steam trap status. Without this training and instrumentation, the wasted steam exits the boiler plant undetected. With the old type bucket traps, a trained operator could detect a faulty trap. With traps used today digital infrared temperature scanners are needed to detect steam trap leaks.

2. Boiler operators as well as boiler plant managers with fiscal responsibility apparently fail to realize that steam trap maintenance and efficient boiler plant operation exerts a positive influence on the bottom line. This positive influence grows as fuel and boiler feed water treatment chemical costs escalate at a pace exceeding the inflation rate.

3. Neglected steam leaks, which can be assessed with condensate return data, result in added fuel costs and increased NOx emissions. A condensate return value of 85% or better establishes a reasonable goal.

Estimates by consultants and specialists in this area suggest that many Non-EGU type boiler plants in Virginia can reduce their energy waste and NOx emissions by 20% by allocating resources to reduce the waste outlined in this report.

In view of this background information and the advice of experts in the field perhaps as much as 25%, of the industrial boiler NOx budget

(1,725 tons of NOx per ozone season) can be acquired with a regulatory initiative to credit industrial boiler sources for documented improvements. The cost of this approach appears to be modest in view of energy cost savings when compared to the cost of $2000/ton to $8,000/ton end of pipe retrofits for NOx reduction.

The State Advisory Board recommends that the Commonwealth implement a demonstration program at a typical state owned Non-EGU boiler plant to document the fuel cost savings and the NOx reductions achieved by implementing the operation and maintenance improvements discussed in this report. This would provide a documented reference for boiler facilities operated by state, county, and local governments as well as those in the private sector to use in meeting NOx reductions during the ozone season. The regulatory framework would relate NOx reduction credits for increasing the efficiency of Non-EGU operations by the following:

- Energy audits to determine how fuel is being wasted
- Improved operation with respect to fuel combustion efficiency
- Improved maintenance, including steam trap testing and steam leak reductions to increase condensate returns
- Improved training of operators and availability of instrumentation

The issue of how this recommendation might be implemented received considerable attention from the Committee. The situation for government-owned boilers should be noted as being different from privately owned and operated boilers.

Government-owned boilers contribute a substantial amount of the NOx emitted in Virginia. Some of these sources (primarily schools), however, operate little during the summer ozone season since the need for comfort heating is small during the ozone season. Colleges and other state facilities operate boilers in the summer for central hot water heating and in some cases to drive central refrigeration and air conditioning chiller units.

Since energy conservation is desirable for reasons other than reducing NOx, there may be no need, other than conserving state resources, for limiting the program to facilities, like prisons, that operate year-round.

The Commonwealth, operating through the Department of Mines, Minerals, and Energy and the Department of Environmental Quality can encourage state institutions to improve their energy efficiency. It can also provide education for operators. Energy audits of state boilers should be used as examples to document where the greatest NOx savings can be accomplished.

In the private sector, energy audits and operator training appear to be potential success stories. However, the issue of compliance monitoring arises. The method by which the state can verify NOx emissions reductions that have been acquired through improved operation and maintenance still remains to be determined.

Conceptually compliance can be measured and verified by:

- A requirement that boiler operators submit a plan, for review by the state, for improving fuel efficiency and reducing fuel consumption which thereby reduces NOx emissions.
- A requirement that boiler operators report reductions in fuel consumption achieved by implementing the submitted plan. Documented improvements in condensate return rates would be an example of a readily available measure of improvement. Multiplying fuel consumption reductions by readily available "emissions factors" would allow the determination of tons of NOx emission reductions per ozone season. Added to that would be the reduction in NOx emissions that would result from increases condensate returns. The payback time of the improvements would be even shorter than it was before the recent escalation of fuel and water treatment chemical costs.

The last approach considered in reducing NOx emissions from Non-EGU facilities deals with the current use of vehicles (mobile sources). Note in Table 1 that no credit exists for conventional highway mobile source NOx reduction strategies. This last approach looks at the situation somewhat differently.

Employees drive to work at Non-EGU type plants as well as other plants. It seems reasonable to allow NOx reduction credits for programs implemented by these plants that result in documentable reductions in vehicle NOx emissions in regard to commuting to work. These reductions during the ozone season could come from programs that reduces the miles driven by fuel burning cars on the way to and from work. In Europe, for example, the parking lots at plants with a given employment are much smaller than the parking lots for plants in the United States. This suggests that excessive NOx emissions come from commuting to work.

A NOx reduction occurs when commuting jobs convert to telecommunication jobs that do not require driving to work. This reduction in NOx emissions could be credited to the Commonwealth's SIP proposal to achieve the NOx reduction budget. These reductions could then be used to reduce the NOx reductions that Non-EGUs must achieve.

When a plant ceases operations the SIP could also be designed to credit the Commonwealth with NOx reduction credits. When a new Non-EGU source applies for a permit the mobile NOx component would be included. The source management would then be aware of the opportunity to receive credit for novel plans for their new employees to come to work. An example would be to use satellite parking lots with electric transit between the satellite lots and the plant. Plant expenditures could then be allocated to NOx reductions, which could come from some optimum minimum cost combination of mobile source NOx reductions and NOx reductions at the plant itself.

4. Conclusions

The largest Non-EGU NOx sources in Virginia offer the largest potential for NOx emissions reductions when compared to the smaller Non-EGU NOx sources. However, only a small number, perhaps 18, large Non-EGU units that exceed 250 mmBtu /hour size operate in Virginia. These non-EGU units are not required to add NOx control under Title IV. Title IV only applied to EGUs unless a Non-EGU unit exercised the option of participating in Title IV. In Virginia no Non-EGU units are known to have taken the option to participate.

Calculations conducted within the DEQ office of Air Data Analysis indicate that Non-EGU sources between 100 and 250 mmBtu/hour with NOx controlled to 0.3 lb/mmBtu can achieve an estimated reduction of 2,148 tons per ozone season. Only annual NOx emissions data currently exists. To address ozone season emissions, $\frac{5}{12}$ of the annual emissions were used in the process of arriving at the 2148 tons of NOx per ozone season. When the projected NOx per ozone season reduction from boiler operations upgrades, 1725 tons per ozone season is added to the 2,148 the sum of 3873 tons per ozone season results. This 3873 falls significantly below the required 6892 value. Therefore, both the 18 large Non-EGU sources of NOx and the smaller sources must cut emissions significantly to meet the required SIP call reduction.

A conclusion then is that the 6892 tons per ozone season of NOx reductions must come from a cooperative effort of (1) smaller than 100 mmBtu/hr sources, (2) the 100-250 mmBtu/hr sources (3) the larger than 250 mmBtu/hr sources, (4) boiler operation upgrades and (5) energy management improvements.

The emission inventory for the 100-250 mmBtu/hr sources contains annual NOx emissions values for those sources. To address ozone season emissions, $\frac{5}{12}$ of the annual emissions were used in the process of arriving at the 2148 tons of NOx per ozone season. This assumption neglects the fact that space heating drops drastically during most of the ozone season. The ozone season emission of NOx needs to be added to the emissions inventory.

Since sources in the size range smaller than 100 mmBtu/hr (small businesses) must contribute to the NOx reduction program, the Office of Small Business Assistance will need to play a significant role.

Additional data and analysis is needed to determine the fraction of NOx reduction that needs to be contributed by the different sized NOx sources. The information available at this time suggests that all sizes of Non-EGU NOx sources must reduce emissions to meet the Non-EGU NOx to meet the Virginia NOx budget requirement. Upgrades in boiler operational efficiency and energy management efficiency improvements appear to be more cost effective on a per ton NOx reduction basis than NOx stack emissions control equipment.

The reduction of 6892 tons of NOx per ozone season needs to be allocated in an equitable manner among all the NOx sources involved. The sources should then be allowed to participate in the NOx trading program previously developed. This trading would offer the opportunity for all the sources to contribute to the NOx reduction program in the most cost effective manner as determined by the sources at the time.